Capstone Proposed Initial Draft Standard for UAT

22 May 2000

No national standard currently exists for the UAT. This material was prepared to be representative of the UAT data link systems being used in Capstone but including some additional aspects expected to be needed in a national standard. This material is work-in-progress and may not be sufficient to support interoperability with Capstone installations. This material in its current state is being made available to the community for information purposes and to serve as a framework initial draft document to aid development of a national standard for UAT.

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Section 1

Purpose and Scope

1.1 Introduction

The FAA's Capstone Program has selected the Universal Access Transceiver (UAT) as the media for supporting the broadcast data link services to be implemented as part of the program. Specifically these services are listed and defined below:

- ⇒ ADS-B: Automatic Dependent Surveillance-Broadcast is a cooperative service where aircraft or surface vehicles operating within the airport surface movement area periodically transmit their state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is *automatic* because no external stimulus is required; it is *dependent* because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users. The aircraft or vehicle originating the broadcast may or may not have knowledge of which users are receiving its broadcast; any user, either airborne or ground-based, within range of this broadcast, may choose to receive and process the ADS-B surveillance information. ADS-B supports improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety such as conflict management.
- ⇒ TIS-B: Traffic Information Service-Broadcast is a service that uplinks traffic information derived from ground sensors. TIS-B primarily supports the transition toward an ADS-B operational environment by encouraging early equipage.
- ⇒ FIS-B: Flight Information Service-Broadcast is a service that the uplinks weather or other aeronautical information of general interest to pilots. This non-control information may consist of graphical weather images, textual weather data, NOTAMS, SUA status, etc.

Figure 1-1 below shows the services and connectivity supported by UAT.

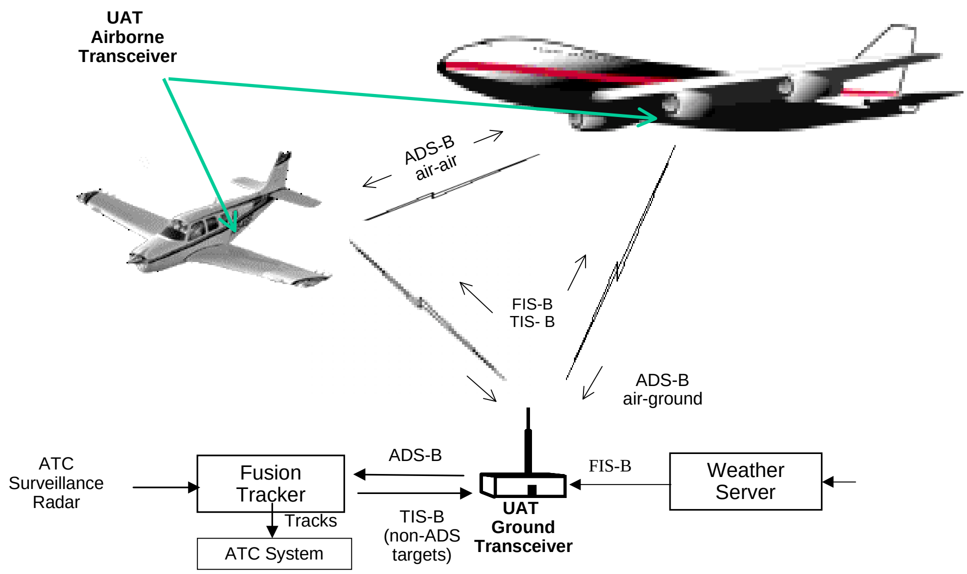

Figure 1-1. UAT Services and Connectivity

This document is not an RTCA-developed Minimum Operational Performance Standard (MOPS); it is an Interim Design Specification (IDS) specifically developed to support the FAA's Capstone Program. The most critical requirement for Capstone is for standards defining the aircraft-based ADS-B transmit function. This is required to support the program's near-term objective of providing ATC "radar-like" services to equipped aircraft in non-radar airspace. The primary objective of this IDS is to provide certification guidance for the ADS-B transmit function. A secondary objective is to provide a framework for future RTCA-based UAT MOPS development.

Since the UAT equipment implementation includes a computer software package, RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, is applicable. When determining the level of software requirements, as defined in RTCA/DO-178B, the equipment manufacturer should consider the criticality appropriate for the installation certification, equipment failure analysis, and the fault monitoring being accomplished.

Section 1 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and, along with RTCA/DO-242, *Minimum Aviation System Performance Standards for ADS-B*, forms the basis for most standards stated in Sections 2 and 3.

Section 2 contains the minimum operational performance standards for the equipment. These standards define required performance under standard operating conditions and stressed physical environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

Section 3 describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational characteristics of the installed equipment, self test features, and controls.

For the purposes of this document, the term *aircraft/vehicle* (A/V) will refer to either 1) a machine or device capable of atmospheric flight, or 2) a vehicle on the airport surface movement area (i.e., runways and taxiways). For simplicity, the word *aircraft* is used to refer to aircraft and vehicles, where appropriate.

1.2 System Overview

The UAT is a wideband data link that operates on a single global channel. The channel signalling rate is just over 1Mbps. The UAT media supports multiple broadcast services through a hybrid media access approach that incorporates assigned time slotted and random unslotted access. There are two basic transmission types--or *messages*--on the UAT channel: the ADS-B message and the Ground Uplink message. Each message type has two fundamental components: message *payload*—which contains user information, and message overhead--which supports the physical layer transfer of the data.

The subsections below establish the necessary context for the requirements and test procedures of Section 2. In particular are key system-level principles of operation and some important system terminology that will be used throughout the document.

1.2.1 UAT Shared Media Access

Figure 1-1 illustrates the timing structure for UAT message transmissions. In the UAT system, the *frame* is the most fundamental time unit. Frames are one second long and begin at the start of each UTC (or GPS) second. Each frame is divided into two segments: one segment in which Ground Uplink messages occur, and another in which ADS-B messages occur.

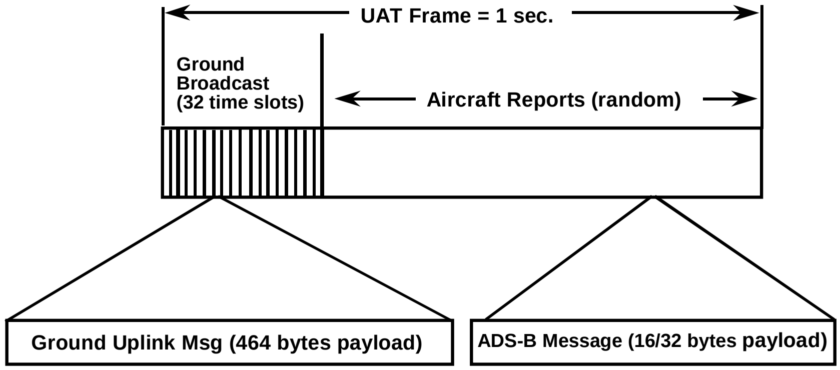

Figure 1-2. UAT Timing Structure

Each segment is further subdivided into message start opportunities (MSOs) spaced 250 μs apart for a total of 4,000 MSOs per frame. The MSO is the smallest time increment used for scheduling Ground Uplink message or ADS-B message transmissions.

1.2.1.1 Scheduling of Ground Uplink Message Transmission

The ground broadcast segment consists of 752 MSOs, for a total of 188 milliseconds (ms). These 752 MSOs are divided into 32 ground broadcast slots, each 22 MSOs long, plus a guard interval of 48 MSOs (12 ms). Each ground station is assigned one or more of the 32 time slots, in such a way that nearby ground stations in range can always be received without interference. Each ground station transmits a Ground Uplink message each second in each assigned time slot. Figure 1-3 shows details of the MSO-based timing.

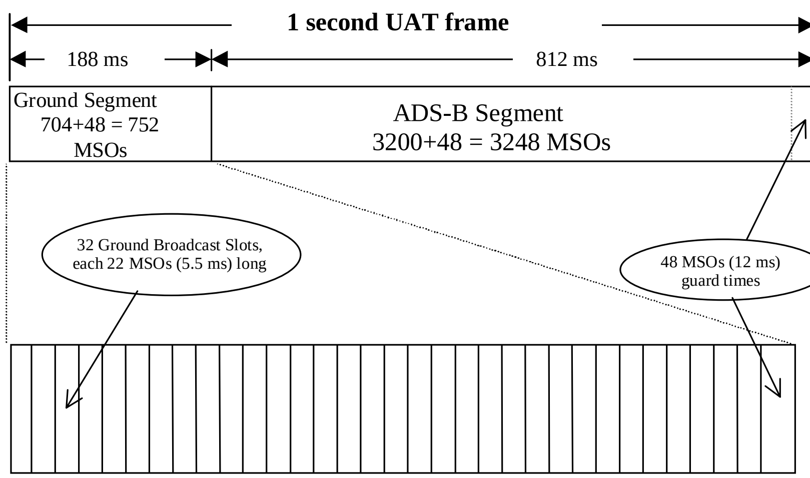

Figure 1-3. Detailed View of MSO-Based Timing

A Ground Uplink message occupies just over 4 milliseconds, and each slot is 5.5 ms long. The resulting gap allows for over 200 nautical miles (nmi) of propagation guard time between the Ground Uplink messages.

1.2.1.2 Timing of ADS-B Message Transmissions

Each A/V makes exactly one ADS-B message transmission during each one second frame. During each frame, every A/V selects—on a psuedorandom basis—from among the first 3200 MSOs in the ADS-B segment to determine its message start time. This random selection is intended to prevent two aircraft from repeatedly interfering with each other's ADS-B message transmissions. Guard time--specifically for timing drift--is accommodated at both the beginning and end of the ADS-B segment. This could accommodate clock drift in airborne units for a period of time before there were any possibility of ADS-B transmission overlap with a ground message. Compliance with this MSO-based timing scheme is required in order to support range validation of ADS-B messages by a receiver.

1.2.2 ADS-B Message Composition and Scheduling

Each ADS-B message payload is composed of two parts: the Basic State Vector (SV) payload and optionally the Supplemental payload. Every ADS-B message contains the Basic SV payload. The Basic ADS-B message contains only the Basic SV payload. Extended ADS-B messages contain the Basic SV payload plus a Supplemental payload. Basic and Supplemental payloads are fixed at 16 bytes each. There are multiple types of Supplemental payloads; each type is identified in the payload. Figure 1-4 below shows the relationship of ADS-B message types to their constituent payloads.

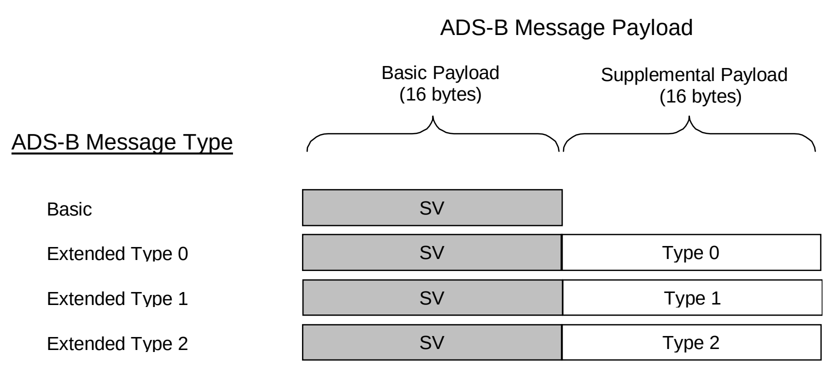

Figure 1-4. ADS-B Message Types and Components

The complete (unsegmented) SV data in the Basic payload, is the most dynamic of all data included in ADS-B. This payload is therefore part of every transmitted message. This means that SV data is always transmitted at a 1 hz average rate. Furthermore, this means that unique addressing is not absolutely necessary for association of the various ADS-B message types from a given A/V; i.e., SV data could also be used for this purpose.

The transmission rate of each of the message types is determined by the availability of data that are contained in the various Supplemental payloads. At one extreme, a surface vehicle with a self-contained transmitter may transmit only the Basic message. An A2 or A3 level user may use only the Extended message types in a defined rotation cycle. Scheduling of message types for transmission is based on a specified message rate per *transmission epoch*. Within each transmission epoch, each A/V is required to transmit at least one of each message type required. Detailed requirements and procedures for payload composition and message transmission are included in Section 2.2.4 and 2.2.5.

1.2.3 Generation of Reports

Reports are generated within an airborne receiving subsystem for use by the airborne application systems. Reports are generated in response to messages received (ADS-B or Ground Uplink). The conditions and procedures for generation of reports are straightforward: each message successfully received will trigger the generation of a report. Each report includes the unaltered payload of the message just received. This same procedure applies to both ADS-B and Ground Uplink messages.

1.2.4 Airborne Implementation and Scope

Implementations will consist of transmit and receive subsystems. Most implementations will include both subsystems; however, transmit-only configurations are also possible. The primary scope of this document is illustrated by the dark grey area in Figure 1-5 below. The applicable requirements sections are shown in parenthesis relative to each function.

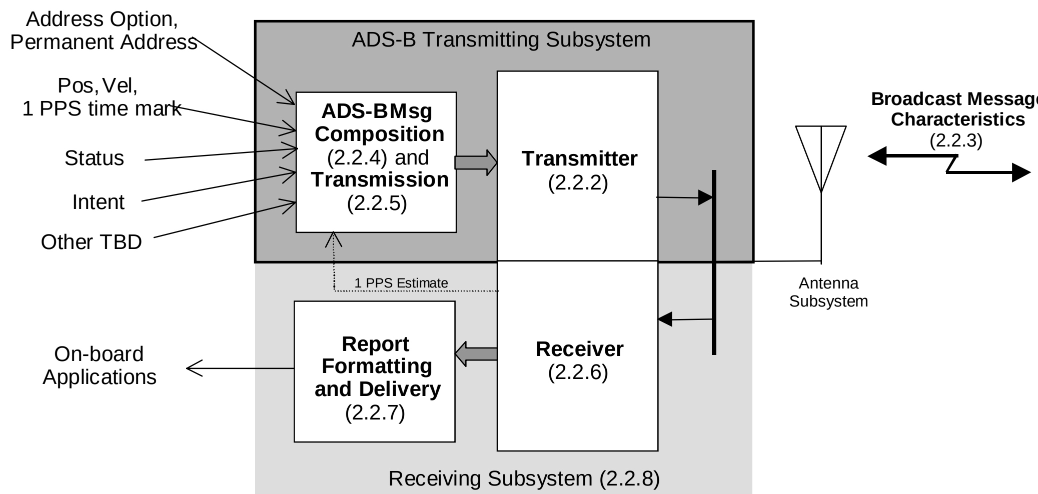

Figure 1-5. UAT Avionics Configuration

1.2.5 Role of the Ground Station

The UAT ground station will operate as an ADS-B sensor identically to that of airborne units. The ground subsystem will also be capable of transmitting Ground Uplink messages in one or more of the 32 assigned Ground Segment time slots. TIS-B uplink from ground station will utilize the ADS-B message format and the ADS-B segment of the UAT frame; the avionics receiving subsystem makes no distinction in its processing of ADS-B and TIS-B data—although the airborne application can distinguish these via the 25-bit UAT address. The typical ground station antenna is a 6-8 dBi omni DME-style. Figure 1-6 gives an overview of the ground station.

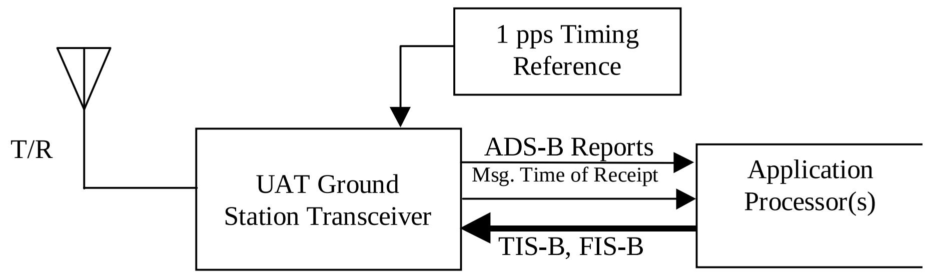

Figure 1-6. Evaluation Unit Ground Station Block Diagram

A single ground station antenna/transceiver is capable of supporting the following functions:

- ADS-B sensor
- Provides time-of-arrival measurement of ADS-B transmission for independent range to target measurement based on a single sensor. Networked ground stations with overlapping coverage allows surveillance based on the “multilateration” technique wherein a 2-D position is derived completely independent of the ADS-B reported position.
- FIS-B uplink
- TIS-B uplink
- Provides timing beacon to airborne users that can serve as backup timing (see Section 2.2.5.1) or potentially as backup navigation.

1.2.6 Address Plan

The UAT address plan accommodates the 24-bit ICAO aircraft address. This address is permanently assigned to the airframe and is guaranteed to be unique. In addition, the UAT address plan expands on the 24-bit ICAO address with a 25th extension bit. This extension gives an additional 24-bit space to accommodate additional functionality. First, it allows for an address block for various types of ADS-B transmitters that may need to be distinguished or filtered by airborne applications(e.g., Cockpit Display of Traffic Information—CDTI). Since the 25-bit UAT address is included within the SV component of the payload, every received ADS-B message contains all information necessary for basic CDTI target display maintenance. Additionally, some users may not wish to divulge a permanent airframe address; instead a temporary randomly generated, self-assigned address can be substituted. This mechanism fulfills the anonymity requirement in DO-242. Table 1-1 below shows the 25-bit UAT address plan.

Table 1-1. 25-Bit UAT Address Plan

Address Bits									Address Block Allocation
Ext	23	22	21	20	19	18	17	16-0	
0	-	-	-	-	-	-	-	-	Permanent (unique) aircraft address
1	0	0	0	0	0	-	-	-	TIS-B aircraft reports (airborne and surface)
1	0	0	0	0	1	0	0	-	Surface vehicles
1	0	0	0	0	1	0	1	-	Fixed obstructions
1	0	0	0	0	1	1	0	-	System monitor beacons (e.g., "parrot")
1	0	0	0	0	1	1	1	-	<spare>
1	0	0	0	1	0	0	0	0	Temporary self assigned (non-unique) ADS-B aircraft address
through									
1	1	1	1	1	1	1	1	1	

"-" denotes bit can be zero or one

1.3 Assumptions and Rationale

1.4 Test Procedures

1.5 MASPS Compliance

1.6 Definition of Key Terms

The definition of some key terms used throughout the document is provided below.

⇒ UAT Frame- The one second interval between UTC (GPS) one second time marks

- ⇒ Transmission Epoch – The interval within which any required ADS-B message is transmitted at least once. This corresponds to 4 UAT frames (or seconds).
- ⇒ Message – The actual RF transmissions on the UAT channel. There are fundamentally two message types: ADS-B messages and Ground Uplink messages
- ⇒ Message Payload – The portion of the message that carries data that will be consumed by application systems outside the UAT system.
- ⇒ Field – The elements of ADS-B message payload. Most of these elements are enumerated in RTCA DO-242 (e.g., Latitude, Longitude, etc.)
- ⇒ Reports – The encapsulated payload of received messages that is forwarded to on-board application processors

Section 2

Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.1.1 Airworthiness

In the design and manufacture of the equipment, the manufacturer shall provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment shall perform its intended function(s), as defined by the manufacturer, and its proper use shall not create a hazard to other users of the National Airspace System.

2.1.3 Federal Communications Commission Rules

All equipment shall comply with the applicable rules of the Federal Communications Commission.

2.1.4 Fire Protection

All materials shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note: One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.

2.1.5 Operation of Controls

The equipment shall be designed so that controls intended for use in flight cannot be operated in any position, combination or sequence which would result in a condition detrimental to the reliability of the equipment or operation of the aircraft.

2.1.6 Accessibility of Controls

Controls which do not require adjustment during flight shall not be readily accessible to flight personnel.

2.1.7 Equipment Interfaces

The interfaces with other aircraft equipment shall be designed such that, properly installed with adequately designed other equipment, normal or abnormal ADS-B equipment operation shall not adversely affect the operation of other equipment nor shall normal or abnormal operation of other equipment adversely affect the ADS-B equipment except as specifically allowed.

2.1.8 Effects of Test

The equipment shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

2.1.9 Design Assurance

The equipment shall be designed to the appropriate design assurance level(s) based on the intended application of the equipment and aircraft class in which it is to be installed. The appropriate design assurance level(s) are determined by an analysis of the failure modes of the equipment and a categorization of the effects of the failure on the operation of the aircraft. For the purpose of this analysis, a failure is defined as either a loss of function or the output of misleading information. Additional guidance is contained in Advisory Circulars AC 23.1309-1C and AC 25.1309-1A.

Software included as part of the equipment shall be developed in compliance with the appropriate software level as defined in RTCA/DO-178B Software Considerations in Airborne Systems and Equipment Certification.

2.1.10 Equipage Class Application Coverage

UAT equipment is categorized into aircraft system equipage based on the ADS-B equipage classes established in RTCA document #DO-242 and is summarized in Table 2-1. These class categories are based on both the aircraft's on-board transmitter and receiver capabilities. For UAT, no distinction is required for receiver operation amongst these classes; the distinction is limited to transmitter power level and information available to the transmitter.

Table 2-1. UAT Installed Equipment Classes for Mobile Use

Application	DO-242 Equivalent Equipage Class	Transmit Power Required[1]	Antenna Diversity[2]
Basic Surveillance (Tx only)	B1	Medium (<15,000' max altitude) High (>15,000'max altitude)	Yes
	B2	Low	No
Class B plus receiver for G-A and A-A services	A0, **A1**[3]	Medium (<15,000' max altitude) High (>15,000'max altitude)	Yes
Installation Class A1 plus additional transmitted data to support additional applications	**A2**[4], A3	High	Yes

Other notes[5],[6],[7]

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[1] Transmitter power requirements are driven by A/G surveillance needs for Class B and A1 and by air-air needs for Class A2:

-Low →[5]W,

-Medium→ [25]W,

-High→ [125]W,

(all as measured at the antenna terminals)

[2] True receiver diversity with time shared transmission [may] be required for Class A2 installations. All other Classes may use time shared receiver/transmitter switching

[3] "A1" will be used to designate this UAT equipment class

[4] "A2" will be used to designate this UAT equipment class

[5] No distinction in receiver sensitivity requirements is made; all receivers have the same requirements driven by its ground-air uplink use.

[6] Airborne (ownship) applications supported by Class A1 or A2 installations will be determined by the application processor which is outside the scope of UAT.

[7] No distinction in receiver processing capability is made amongst installation classes. This is because the receiver's message-to-report conversion procedures are consistent for any application use of data.

2.2 Equipment Performance - Standard Conditions

2.2.1 Definition of Standard Conditions

2.2.1.1 Signal Levels

Unless otherwise noted, the signal levels specified for transmitting devices in this subsection exist at the antenna end of a transmitter-to-antenna transmission line of loss equal to the maximum for which the transmitting function is designed.

Likewise, unless otherwise noted, the signal levels specified for receiving devices in this subsection exist at the antenna end of an antenna-to-receiver transmission line of loss equal to the maximum for which the receiving function is designed.

NOTE: *Transmitting or receiving equipment may be installed with less than the designed maximum transmission line loss. Nevertheless, the standard conditions of this document are based on the maximum design value. Insertion losses internal to the antenna should be included as part of the net antenna gain.*

2.2.1.2 Desired Signals

The desired signal specified as part of receiver performance requirements is any valid ADS-B Extended Type message.

2.2.2 ADS-B Transmitter Characteristics

2.2.2.1 Transmission Frequency

The transmission frequency shall be [981] MHz +/- [20] PPM.

2.2.2.2 Modulation Rate

The modulation rate shall be 1.041667 megabaud/second +/- [100] PPM. Each baud represents one bit.

NOTE: Ground Uplink Messages will use the same modulation type and rate. However, the rate tolerance for these messages will be +/- 10 PPM to support proper demodulation over their longer duration.

NOTE: Each baud represents one bit thus making each bit period 0.96 microsecond

2.2.2.3 Modulation Type

Data shall be modulated onto the carrier using binary Continuous Phase Frequency Shift Keying. The modulation index, *h*, shall be 0.6; this implies that if the data rate is R_b, then the nominal frequency separation between "mark" (binary 1) and "space" (binary 0) is $\Delta f = h \bullet R_b$. A binary 1 shall be indicated by a shift up in frequency from the nominal carrier frequency of $\Delta f/2$ (+312.5 kHz) and a binary 0 by a shift of $-\Delta f/2$ (-312.5 kHz). These frequency deviations shall apply at the optimum sampling points for the bit interval.

NOTE: Filtration of the transmitted signal will be required to meet the spectral containment requirement of Section 2.2.2.5. This filtration will cause overshoot in the deviation, making the maximum deviation close to +/-450 kHz at points outside the optimum sampling point.

2.2.2.4 Transmitter Output Power

2.2.2.4.1 Minimum Power During the Active State

The minimum RF peak output power for each UAT equipment class shall be as given in Table 2-1.

2.2.2.4.2 Maximum Power During the Active State

The maximum RF peak output power of each transmitted message at the terminals of the antenna shall be fixed at [125W] for all classes of equipment.

2.2.2.4.3 Maximum Power During the Inactive State

When the transmitter is in the inactive state, the RF output power at the antenna terminals shall not exceed –80 dBm when measured at f_0 in a 1 MHz bandwidth.

NOTE: The inactive state is defined to include all time other than the time required for ADS-B message transmission. ADS-B message transmission is inclusive of the time allowed for ramp up and ramp down intervals as defined in Section 2.2.3.1.

NOTE: This unwanted power requirement is necessary to ensure that the ADS-B transmitter does not prevent closely located UAT receiving equipment from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment antenna exceeds 20 dB.

2.2.2.5 Transmission Spectrum

[To be provided]

2.2.2.6 Spurious Emissions

[To be provided]

2.2.3 Broadcast Message Characteristics

2.2.3.1 ADS-B Message Format

The ADS-B Message format is shown in Figure 2-1. Each message element is described in detail in the subsections that follow.

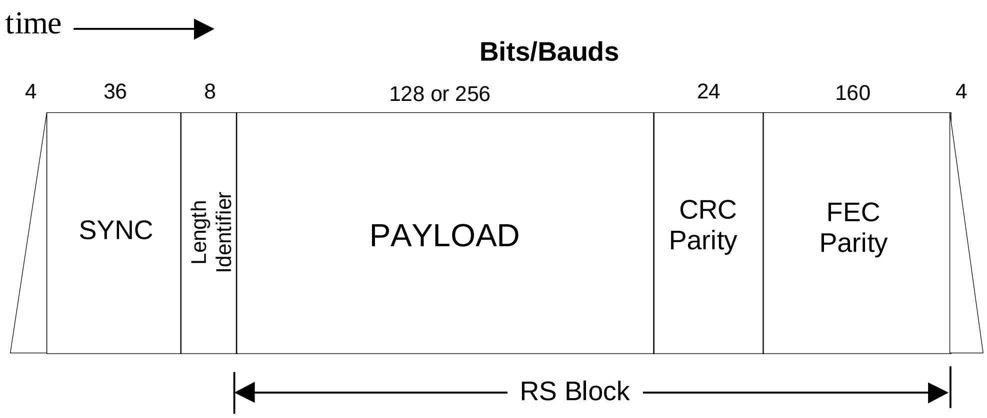

Figure 2-1. ADS-B Message Format

2.2.3.1.1 Ramp Up/Down

To minimize transient spectral components, the transmitter power shall ramp up and down at the start and end of each burst. The maximum time duration of these ramps shall be no more than 4 bit periods each. Ramp up time is defined as the time between the transmitter "off" level to 90% power output. Ramp down time is defined as the time to decay from full power to –80 dBm at the antenna terminals. During ramp up and down, the modulating data shall be all zeroes.

2.2.3.1.2 Synchronization

Following ramp up, each data burst shall include a 36 bit synchronization sequence. For the ADS-B messages the sequence shall be

111010101100110111011010010011100010

with the left-most bit transmitted first.

2.2.3.1.3 Length Identifier

As indicated in Figure 2-1, the ADS-B message payload can be either 128 or 256 bits long. When the payload length is 128 bits, the length identifier field shall be encoded as 00001111 with the left-most bit transmitted first. When the payload length is 256 bits, the length identifier field shall be encoded as 11110000 with the left-most bit transmitted first.

2.2.3.1.4 Payload

The format and encoding of the message payload is defined in Section 2.2.4.

2.2.3.1.5 CRC Parity

The sequence of 24 CRC parity bits ($P_1, P_2, \ldots P_{24}$) is generated from the sequence of information bits ($m_1, m_2, \ldots m_k$) where k is 128 or 256 for Basic or Extended length message payloads respectively. The particular code used is the CRC-24Q code, for which the generating polynomial is

$$GP(X) = X^{24} + X^{23} + X^{18} + X^{17} + X^{11} + X^{10} + X^{7} + X^{6} + X^{5} + X^{4} + X^{3} + X + 1.$$

When by the application of binary polynomial algebra, the above $GP(X)$is divided into $m(X)X^{24}$,where the information sequence m(X) is expressed as

$$m(X) = m_k + m_{k-1}X + m_{k-2}X^2 + \cdots + m_1 X^{k-1}$$

the result is a quotient and a remainder R(X) of degree < 24. The bit sequence formed by this remainder shall be the CRC parity field. Parity bit P_i for any i from 1 to 24, is the coefficient of X^{24-i} in $R(X)$. The CRC parity bits shall be transmitted in order starting with P_1.

2.2.3.1.6 FEC Parity

FEC Background

Forward error correction (FEC) is provided for the payload and CRC parity fields by using Reed-Solomon (RS) coding. The RS code is defined over the finite field GF (2^8). The primitive polynomial is given by

$$P(x) = x^8 + x^7 + x^2 + x + 1;$$

and the generator polynomial is

$$G(x) = \prod_{i=120}^{119+R} \left(x - \alpha^i\right),$$

where R = N - K for a RS(N,K) code. This code conforms to the Intelsat IESS/308 Revision 6B international standard.

FEC Applied to ADS-B Messages

FEC Parity shall be generated based on the use of reduced versions of the RS (255, 249) code. When the payload is 128 bits, the code is reduced to a RS (25, 19) code. When the payload is 256 bits, the code is reduced to a RS (41, 35) code. In each case, the coded information K shall be inclusive of the CRC Parity field.

NOTE: Bit ordering of FEC parity bits is established by way of the message encoding example provided in Appendix A. [To be provided]

2.2.3.2 Ground Uplink Message Format

Figure 2-2 shows the format of the Ground Uplink message transmitted from ground stations.

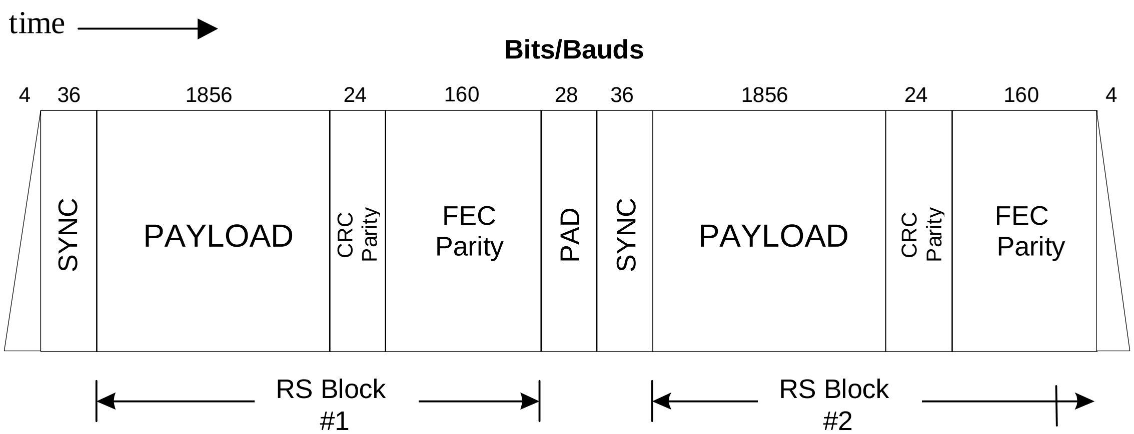

Figure 2-2. Ground Uplink Message Format

NOTE: The Ground Uplink message format differs from the ABS-B message format in the following ways:

- *There is no "length identifier" field, because transmissions from ground stations are always the same length.*
- *The burst is organized into two Reed-Solomon blocks rather than one.*

– *The payloads and FEC fields in those blocks are longer than in the shorter ADS-B block. (With more payload bits to be protected, a longer Reed-Solomon forward error correcting code is required.)*

2.2.3.2.1 Synchronization

The polarity of the bits of the synchronization sequence is reversed from that used for the ADS-B message, that is, the ones and zeroes are interchanged. This synchronization sequence is

000101010011001000100101101100011101

with the left-most bit transmitted first.

NOTE: Because of the close relationship between the synchronization sequences used for the ADS-B and Ground Uplink Messages, the same correlator can search for both simultaneously.

2.2.3.2.2 Message Payload

The format and encoding of the message payload is outside the scope of this document. Appendix B provides some information on the payload.

2.2.3.2.3 CRC Parity Fields

The requirements of Section 2.2.3.1.5 applies with the exception that the number of information bits *k* over which the CRC parity is generated is 1856.

2.2.3.2.4 FEC Parity Fields

FEC Parity is generated for each of two RS blocks based on the use of the RS (255,235) code. In each case, the coded information K is inclusive of the CRC Parity field.

NOTE: See Section 2.2.3.1.6 for FEC background

2.2.4 The ADS-B Message Payload

2.2.4.1 Basic SV Payload Format and Encoding

This subsection establishes the format and encoding of the Basic SV Payload. Table 2-2 shows the format of the individual fields of the payload. Bytes are transmitted in ascending order starting with byte #0. Within each byte, bits are transmitted in descending order beginning with bit #7. In cases where the encoding of certain fields requires support of a special procedure within the ADS-B transmitting subsystem, that procedure is specified.

Table 2-2. Basic SV Payload Format

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0						. . .	A22	A23 (LSB)
1				**Aircraft Address**				
2	A0 (MSB)	A1	. . .					
3								(LSB)
4				**Latitude (WGS-84)**				
5	(N/S)							
6								(LSB)
7				**Longitude (WGS-84)**				
8	(E/W)							
9	**Addr Ext**	**Turn Indicator**		(MSB)		**NUCp**		(LSB)
10			**N-S Velocity**			(LSB)	**UTC Coupled**	**Hor. Pos. Available**
11			(LSB)	(N/S)				
12	(E/W)			**E-W Velocity**				
13				**Pressure Altitude**				(LSB)
14		**Pressure Altitude Rate**		(LSB)	(MSB)			
15	**Air/Ground State**		(Sign)					

2.2.4.1.1 The UAT 25-Bit Address

The 25-Bit UAT Address field contains a total of 25 bits: a 24 bit Aircraft Address subfield and a 1 bit Address Extension subfield (bit #7 of byte #9). The 25-Bit UAT Address field shall take on one of two possible values determined during initialization as shown in Table 2-3 below.

Table 2-3. Address Field Encoding

Address Option	Addr. Ext. Subfield	Aircraft Address Subfield
Permanent Airframe Address	0	Permanent address assigned to the aircraft
Temporary Self-assigned random address	1	Random bit pattern generated according to procedures in subsection b. below

Special Procedure for Setting Address

The ADS-B transmitting subsystem shall accept the Address Option input and the permanent ICAO 24-bit address via an appropriate data input interface and use such data to establish the “25-Bit UAT Address” field.

a. If the Address Option is selected as “permanent”, then the “Aircraft Address” subfield shall contain the permanent 24-bit ICAO aircraft address. The address Extension subfield shall be set to “0”.

b. If the Address Option is selected as “temporary”, then the “Aircraft Address” subfield shall contain a randomly generated number per the procedure below. This procedure is to be applied only at the time of unit startup or change of state of the Address Option input to “temporary”. The address Extension subfield shall be set to “1”.

Let $ADDR_P$ be the permanent 24-bit ICAO aircraft address. Let M(1) and M(2)be the 12 LSBs of the latitude and longitude fields respectively at the time of startup or change of state of the Address Option input to “temporary”. Define the 24-bit number

$$M(3) = 4096 * M(1) + M(2)$$

The temporary address shall be the modulo 2, bit-by-bit summation of $ADDR_P$ and M(3); i.e.,

$$ADDR_T = ADDR_P \oplus M(3)$$

The $ADDR_T$ value shall then be checked to insure it falls into the address space allocated for temporary self assigned addresses per Table 1-1. If $ADDR_T$ is outside this allocated space, the procedure above shall be repeated by incrementing $ADDR_P$ by 1 using modulo 2^{24} arithmetic until an $ADDR_T$ is found within the allocated space.

2.2.4.1.2 Latitude

The Latitude (WGS-84) field shall be encoded in units of 2^{-24} circles in a signed fractional binary form to represent the range from 0 to 90 degrees of latitude. North is represented by “0” and south is represented by “1” in the “N/S” bit.

2.2.4.1.3 Longitude

The Longitude (WGS-84) field shall be encoded in units of 2^{-24} circles in a signed fractional binary form to represent the range from 0 to 180 degrees of longitude. East is represented by “0” and West is represented by “1” in the “E/W” bit.

NOTE: The above latitude and longitude representations are consistent with conventions used in the ARINC 429 labels 110, 111, 120, and 121 by which an ARINC 743 GPS or GNSS receiver delivers its latitude and longitude outputs.

2.2.4.1.4 NUCp

The NUCp field shall be encoded as specified in Table 2-4 below.

Table 2-4. NUCp Encoding

NAVIGATION UNCERTAINTY CATEGORY - Position			
CODING	**MEANING**		
NUC_P	**Horizontal Protection Limit Error (*)**		**Altitude Type**
0	Unknown or > 20 nmi	*AND*	Baro Altitude
1	< 20 nmi	*AND*	Baro Altitude
2	< 10 nmi	*AND*	Baro Altitude
3	< 5 nmi	*AND*	Baro Altitude
4	< 1 nmi	*AND*	Baro Altitude
5	< 0.5 nmi	*AND*	Baro Altitude
6	< 0.2 nmi	*AND*	Baro Altitude
7	< 0.1 nmi	*AND*	Baro Altitude
8	< 25 m	*AND*	Baro Altitude or GNSS Height error < 15 m
9	< 7.5 m	*AND*	Baro Altitude or GNSS Height error < 4m
10	> 10m	*AND*	GNSS Height error ≥ 15m
11-31	*<Future definition>*		

*Horizontal Protection Limit Error: the radius of a circle in the horizontal plane (local plane tangent to the WGS-84 ellipsoid), with its center being at the true position, such that the probability that the indicated position lies outside this circle is 10^{-7} per flight hour.

2.2.4.1.5 Turn Indicator

The Turn Indicator field shall be encoded in a 2-bit field as shown in Table 2-5 below:

Table 2-5. Turn Indicator Encoding

Byte # 9, bit #: 6	5	**Turn Indication Represented**
0	0	Turn information unavailable
0	1	Turning to the right at >= [TBD] deg/sec
1	0	Turning to the left at >= [TBD] deg/sec
1	1	Turn rate is < [TBD] deg/sec

2.2.4.1.6 Horizontal Position Available

The Horizontal Position Available field shall be set to “1” to indicate that horizontal position (latitude and longitude) information is available. If the horizontal position is unavailable, this bit shall be set to “0”.

2.2.4.1.7 UTC Coupled

The UTC Coupled field shall be set to “1” to indicate:

a. that the transmitter is receiving a valid 1 PPS second UTC time mark from its GPS/GNSS receiver, AND

b. that the 1 PPS UTC time mark represents the time of validity for position and velocity information

This field shall be set to “0” otherwise.

2.2.4.1.8 N-S Velocity

The N-S Velocity field shall be encoded as a signed twos-complement binary number to represent the N-S component of the aircraft’s horizontal velocity. North is indicated by “0” and south is indicated by “1” in the “N/S” bit.

The range and resolution of this field is determined by the encoding of the “Air/Ground State” field as described in Section 2.2.4.1.12

The ALL ONES encoding shall represent “N-S Velocity information unavailable”.

2.2.4.1.9 E-W Velocity

The E-W Velocity field shall be encoded as a signed twos-compliment binary number to represent the E-W component of the aircraft’s horizontal velocity. East is indicated by “0” and West is indicated by “1” in the “E/W” bit.

The range and resolution of this field is determined by the encoding of the “Air/Ground State” field as described in Section 2.2.4.1.12

The ALL ONES encoding shall represent “E-W Velocity information unavailable”

2.2.4.1.10 Pressure Altitude

The Pressure Altitude field shall be encoded as a 12-bit unsigned numeral representing (altitude + 1000 feet) in 25-foot units as shown in the Table 2-6 below. The “all ones” encoding shall represent “pressure altitude information is unavailable.”

Table 2-6. Pressure Altitude Encoding

Encoded Value (MSB … LSB)	Meaning
0 0 0 0 0 0 0 0 0 0 0 0	-1000 feet
0 0 0 0 0 0 0 0 0 0 0 1	-975 feet
•••	
0 0 0 0 0 0 1 0 0 1 1 1	-25 feet
0 0 0 0 0 0 1 0 1 0 0 0	0 feet
0 0 0 0 0 0 1 0 1 0 0 1	25 feet
•••	
1 1 1 1 1 1 1 1 1 1 1 0	101350 feet
1 1 1 1 1 1 1 1 1 1 1 1	Pressure altitude unavailable

2.2.4.1.11 Pressure Altitude Rate

The Pressure Altitude Rate field shall be encoded as a 10-bit signed twos complement binary numeral, in units of 64 feet per minute. Ascents at rates of 32704 feet/minute or more shall be encoded as the maximum positive 10-bit binary numeral (binary 0111111111), while descents at rates 32768 feet/minute or more shall be encoded as the most-negative possible 10-bit binary numeral (1000000000). All ONES shall be used to indicate "data unavailable".

2.2.4.1.12 A/G State

The Air/Ground State field shall be encoded in bits 6 and 7 of byte #15. The encoding resolution of the N-S velocity and E-W velocity fields shall be dependent on the A/G State according to Table 2-7 below.

Table 2-7. A/G State Encoding

Byte # 15, bit #: 7	6	A/G State Information Represented	Encoding of N-S and E-W Velocity Fields
0	0	Whether the aircraft is airborne or not is unknown.. *A/G State 0*.	Shall be encoded to 0.5 knot resolution
0	1	The aircraft (or surface vehicle) is known to be on the ground. *A/G State 1*.	Shall be encoded to 0.25 knot resolution.
1	0	The aircraft is known to be airborne, with a speed less than 1023 knots. *A/G State 2*.	Shall be encoded to 1.0 knot resolution.
1	1	The aircraft is known to be airborne, with a speed of more than 1000 knots. *A/G State 3*.	Shall be encoded to 4.0 knot resolution.

Special Procedures for Setting A/G State

a. If there is a means to automatically determine the vertical status of the ADS-B emitter category (i.e., weight on wheels), then such information shall be used to set “A/G State 1”.

b. If there is no means to automatically determine the vertical status of the ADS-B emitter category, then the A/G State shall be configured to always report “A/G State 0” for all ADS-B emitter categories except the following, which shall be configured to report “A/G State 1”:

-Surface Vehicle - Emergency Vehicle

-Surface Vehicle – Service Vehicle

-Fixed Ground or Tethered Obstruction

2.2.4.2 Type 0 Supplemental Payload Format and Encoding

This subsection establishes the format and encoding of the Type 0 Supplemental Payload. Table 2-8 shows the format of the individual fields of the payload. Bytes are transmitted in ascending order starting with byte #16. Within each byte, bits are transmitted in descending order beginning with bit #7.In cases where the encoding of certain fields requires support of a special procedure within the ADS-B transmitting subsystem, that procedure is specified.

Table 2-8. Type 0 Supplemental Payload Format

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
16	*Future Definition*					Payload Type Code: 0		
17	Geodetic Height Difference							(LSB)
18	Emergency/Priority Status			Ht. Valid	(Sign)			
19	(Sign)	Geodetic Height Difference Rate						(LSB)
20	*Future Definition*							
21								
22								
23								
24	Compound Byte Pair #1							(LSB)
25	(MSB)	(Aircraft Category, and Flight ID characters 1 and 2)						
26	Compound Byte Pair #2							(LSB)
27	(MSB)	(Flight ID Characters 3, 4, and 5)						
28	Compound Byte Pair #3							(LSB)

29	(MSB) (Flight ID Characters 6, 7, and 8)	
30	**Message Start Opportunity (MSO)** (LSB)	
31	***Future Definition***	(MSB)

2.2.4.2.1 Payload Type Code

The Payload Type Code field is used to identify the Supplemental Payload that is being conveyed in the Extended Length ADS-B Message. The encoding of this 3 bit field shall be as indicated in Table 2-9 below.

Table 2-9. Payload Type Field Encoding

Byte # 15, bit #:			**Meaning**
2	1	0	
0	0	0	Type 0 Supplemental Payload
0	0	1	Type 1 Supplemental Payload
0	1	0	*future definition*
	through		
1	1	1	

2.2.4.2.2 Reserved *Future Definition*

2.2.4.2.3 Geodetic Height Difference

The Geodetic Height Difference field shall be encoded as a 12-bit signed twos compliment binary numeral in which the LSB has a weight of 2 feet. The encoding shall be such that the Geodetic Height Difference added to the Pressure Altitude (which has been rounded to the nearest 25 or 100 feet) results in the geometric altitude to two-foot resolution.

(geodetic height difference) = (geodetic height) – (pressure altitude).

2.2.4.2.4 Height Valid

The Height Valid field shall be encoded as “1” if a valid geodetic height is available from the GPS receiver, or “0” if a valid geodetic height is not available.

2.2.4.2.5 Emergency/Priority Status

The Emergency/Priority Status field shall be encoded per Table 2-10 below.

Table 2-10. Emergency/Priority Status Encoding

Byte # 18, bit #:	**Meaning**

2	1	0	
0	0	0	No emergency/Not reported
0	0	1	General emergency
0	1	0	Lifeguard/medical emergency
0	1	1	Minimum fuel
1	0	0	No communications
1	0	1	Unlawful interference (hijacking)
1	1	0	*Spare*
1	1	1	*Spare*

2.2.4.2.6 Geodetic Height Difference Rate

The Geodetic Height Difference Rate field shall be encoded as an 8-bit signed twos complement binary numeral to represent the rate of change of the difference

$$(\textit{geometric altitude}) - (\textit{pressure altitude})$$

The LSB has a weight of 1 foot/minute.

2.2.4.2.7 Reserved *Future Definition*

2.2.4.2.8 Encoding of Compound Byte Pairs

Six bytes (#24 through #29) are used to encode the Aircraft Category and Flight ID subfields. Each of three bytes pairs (#24-#25; #26-#27; #28-29) shall be encoded as the binary equivalent of the base-40 numeral generated as

$$B_2 \times 40^2 + B_1 \times 40 + B_0$$

Where the values of B_2, B_1, and B_0 are given in the subsections below

Byte Pair #1

The Byte Pair #1 field shall be encoded such that

- B_0 represents the Aircraft Category subfield (Section 2.2.4.2.9)
- B_1 represents character #1 of the Flight ID subfield (Section 2.2.4.2.10)
- B_2 represents character #2 of the Flight ID subfield

Byte Pair #2

The Byte Pair #2 field shall be encoded such that

- B_0 represents character #3 of the Flight ID subfield (Section 2.2.4.2.10)
- B_1 represents character #4 of the Flight ID subfield
- B_2 represents character #5 of the Flight ID subfield

Byte Pair #3

The Byte Pair #3 field shall be encoded such that

B_0 represents character #6 of the Flight ID subfield (Section 2.2.4.2.10)
B_1 represents character #7 of the Flight ID subfield
B_2 represents character #8 of the Flight ID subfield

2.2.4.2.9 Aircraft Category Subfield

The Aircraft Category subfield is a 5-bit binary numeral in which the 2 MSBs indicate one of four "participant category sets," and the 3 LSBs specify a particular category within one of those sets. The five-bit category code is regarded as a base-40 digit in the range from 0 to 31. The Aircraft Category subfield shall be encoded as shown in Table 2-11 below.

Table 2-11. Encoding of Aircraft Category Subfield

Base-40 Digit (decimal)	Participant Category	Base-40 Digit (decimal)	Participant Category	Base-40 Digit (decimal)	Meaning
Category Set A, codes 0-7		**Category Set C, codes 16-23**		**Unused Codes (32-39)**	
0	No aircraft type information	16	No participant type information	32	(Unused)
1	Small (< 15500 lbs)	17	Surface vehicle – emergency vehicle	33	(Unused)
2	Medium (15500 to 75000 lbs)	18	Surface vehicle – service vehicle	34	(Unused)
3	Large (75000 to 190 000 lbs)	19	Fixed ground or tethered obstruction	35	(Unused)
4	Extra large (190 000 to 300 000 lbs)	20	Fixed ADS-B Beacon (parrot)	36	(Unused)
5	Heavy (> 300 000 lbs)	21	(Unassigned)	37	(Unused)
6	High performance (> 5G acceleration)	22	(Unassigned)	38	(Unused)
7	Rotorcraft	23	(Unassigned)	39	(Unused)
Category Set B, codes 8-15		**Category Set D, codes 24-31**			
8	No aircraft type information	24	(Unassigned)		
9	Glider/sailplane	25	(Unassigned)		
10	Lighter than air	26	(Unassigned)		
11	Parachutist/sky diver	27	(Unassigned)		
12	Ultra light/ hang glider/ paraglider	28	(Unassigned)		
13	(unassigned)	29	(Unassigned)		
14	Unmanned aerial vehicle	30	(Unassigned)		
15	Space/transatmospheric vehicle	31	(Unassigned)		

2.2.4.2.10 Flight ID Subfield

The Flight ID subfield consists of eight characters, which must be decimal digits, uppercase letters, or the space character. The 37 possible different characters are represented as base-40 digits in the range from 0 to 36. Each character of the Flight ID subfield shall be encoded as shown in Table 2-12 below. The left-most character of the Flight ID corresponds to Character #1; the right-most corresponds to Character #8 in Section 2.2.4.2.8.

Table 2-12. Encoding of Flight ID Subfield

Base-40 Digit (decimal)	Character	Base-40 Digit (decimal)	Character
0	0	20	K
1	1	21	L
2	2	22	M
3	3	23	N
4	4	24	O
5	5	25	P
6	6	26	Q
7	7	27	R
8	8	28	S
9	9	29	T
10	A	30	U
11	B	31	V
12	C	32	W
13	D	33	X
14	E	34	Y
15	F	35	Z
16	G	36	SPACE
17	H	37	(unused)
18	I		
19	J		

Special Procedures for Setting Flight ID Subfield

Each of the 8 characters of the Flight ID subfield shall be encoded using the following procedures.

a. A Flight ID of less than 8 characters shall be padded with spaces in the right-most (trailing) positions.

b. If the aircraft flight plan is available, then the aircraft identification employed in the flight plan shall be encoded.

c. If the aircraft flight plan is not available, then the Aircraft Registration Marking shall be encoded if available.

If no Flight ID information is not available, then the SPACE character shall be encoded in all 8 character positions.

2.2.4.2.11 Message Start Opportunity (MSO)

The Message Start Opportunity field shall be encoded with the binary representation of the MSO pseudorandomly generated for establishing the ADS-B message transmit time for the current frame.

NOTE: There are 4000 possible MSOs in the one-second UAT frame, so a 12-bit field is used.

NOTE: This encoded MSO value allows a receiver to perform a validity check of the range to target by comparing the range indicated by ADS-B to that indicated by the one way propagation time. The airborne receiver uses this MSO value plus the MTOR facility of the receiver (Section 2.2.6.1) to make the propagation time measurement.

2.2.4.2.12 Reserved *Future Definition*

2.2.4.3 Type 1 Supplemental Payload *Future Definition*

NOTE: It is intended that the Type 1 Supplemental Payload be used mainly to convey intent information (e.g., TCP and TCP+1). The format and encoding of this payload is undefined at this time since it is not required for Capstone.

2.2.4.4 Type 2 Supplemental Payload *Future Definition*

NOTE: It is intended that the Type 2 Supplemental Payload be used mainly to convey information beyond that defined in DO-242; it represents the growth capability required in that document. Examples of items this payload could be used for are: airborne meterological observations, providing an indication of ground stations recently heard to aid in monitoring of ground station transmitter performance, and air-air coordination messages. The format and encoding of this payload is undefined at this time.

2.2.5 Procedures for ADS-B Message Transmission

2.2.5.1 The 1 PPS Time Mark

A 1 PPS Time Mark is used by the ADS-B transmitting subsytem to establish the transmission timing and scheduling of ADS-B messages (i.e., the UAT frame) and also may be used to indicate time of validity of position and velocity. The ADS-B transmitting subsystem shall maintain a 1 PPS UTC-based time mark by the reversionary procedure given below:

a. The primary source shall be the GPS/GNSS receiver supplying position, and velocity data. This source shall issue the 1 PPS time mark on the UTC second +/- [1usec]. Availability of this source shall cause the ADS-B transmitting subsystem to be in <u>Timing State 1</u>. The leading edge of the Time Mark shall indicate the exact moment +/- 5 milliseconds that represents the time of applicability of Position and Velocity information received from the GPS/GNSS source.

b. The secondary source shall be derived from receipt of Ground Uplink messages by the receiving subsystem per Section 2.2.9.3. Lack of availability of the primary source and the availability of this secondary source shall cause the ADS-B transmitting subsystem to be in Timing State 2. The leading edge of the time mark does NOT represent a time of validity of position and velocity.

c. The tertiary source shall be derived from a free running clock within the ADS-B transmitting subsystem. Lack of availability of either the primary or secondary source shall cause the ADS-B transmitting subsystem to be in Timing State 3. The leading edge of the time mark does NOT represent a time of validity of position and velocity.

NOTE: Timing State 1 is always the preferred condition. Entry into Timing State 2 or 3 represents a failure of the primary GPS/GNSS navigation source. These reversionary Timing States exist for the following reasons:

-support ADS-B message transmission using an alternate source of position and velocity, if available

-support ADS-B message transmission in absence of position and velocity data in order that any available fields are conveyed (e.g., baro altitude) and that a signal is provided in the event the ground network can perform an ADS-B-independent localization of the A/V (e.g., multilateration)

2.2.5.2 Scheduling of ADS-B Messages

2.2.5.2.1 Message Transmission Epoch

ADS-B message transmissions shall be scheduled based on a message transmission epoch composed of exactly four UAT frame intervals.

NOTE: There is no requirement that transmission epoch boundaries be aligned amongst A/Vs; it is used only to ensure proper mix of transmitted message types.

2.2.5.2.2 Message Transmission Rate

The message scheduling mechanism shall provide the message transmission rates specified in Table 2-14 below based on the availability of data to the ADS-B transmitting subsystem.

Table 2-13. Message Transmission Rate

	Basic	Extended Type 0	Extended Type1	Extended Type 2	Applicable Condition
Message Transmission Frequency per Epoch	4	0	0	0	All Class B systems
	3	1	0	0	All Class A systems when all data fields contained in Type 1 and Type 2 Supplemental payloads are unavailable*
	Future Definition				*Future Definition*

*not including the Payload Type Code

2.2.5.2.3 Transmitter Antenna Diversity

For installations that support ADS-B message transmission from dual (diversity) antennas, the installation shall be configured to transmit through each antenna at one half the rate specified in Section 2.2.5.2.2:

a. On a total message basis per epoch, and

b. Such that each message type scheduled is transmitted from both antennas at least once every two transmission epochs

NOTE: Antenna diversity could be implemented with dual redundant transmitters each connected to its dedicated antenna or from a single transmitter with antenna switching.

2.2.5.2.4 Unavailability of Basic SV Message Payload Fields

a. In any UAT frame interval, each A/V shall at a minimum transmit the Basic ADS-B message regardless of the unavailability of any individual payload field.

b. Any such unavailable payload fields shall be encoded as “unavailable”

2.2.5.3 Message Transmit Timing

2.2.5.3.1 The Message Start Opportunity (MSO)

ADS-B bursts shall be transmitted at discrete Message Start Opportunities (MSO) chosen by a pseudorandom process. The specific pseudorandom number chosen by an aircraft depends on the aircraft’s current position and on the previously chosen random number. The procedure below shall be employed to establish the transmission timing for the current UAT frame *m*.

The desired output of the algorithm is a 12-bit pseudorandom number. Suppose the previous number is R(m-1) and

N(1) = 12 L.S.B.'s of the current latitude

N(2) = 12 L.S.B.'s of the current longitude

where the latitude and longitude are as defined in Section 2.2.4.1.2 and 2.2.4.1.3 respectively. The next random number is then given by

$$R(m) = \{4001 \cdot R(m-1) + N(m \bmod 2)\} \bmod 3200$$

The initial R(m) shall be zero

NOTE: The latitude and longitude alternate in providing a changing "seed" for the pseudorandom number generation.

NOTE: This algorithm provides anonymity to the aircraft and ensures, with very high probability, that no two aircraft will repeatedly choose the same MSO's.

2.2.5.3.2 Relationship of the MSO to the Modulated Data

The leading edge of the first baud of the synchronization sequence shall coincide with the Time Mark offset by 250 usec times the MSO value determined from Section 2.2.5.3.1 to within +/- [250 nanoseconds].

NOTE: This is required to support ADS-B range validation by the receiver

2.2.5.4 Latency of ADS-B Message Payload Fields

2.2.5.4.1 UTC Coupled and Non-UTC Coupled Cases for Position and Velocity

The specification of latency requirements for position and velocity cover two distinct cases:

a. The UTC Coupled case is the condition where the position and velocity data are computed and valid at the 1 PPS UTC time mark also provided by the same navigation system. This case will also correspond to the ADS-B transmitting subsystem being in Timing State 1

b. The Non-UTC Coupled case is the condition where position and velocity data come from an alternate navigation source (non-GPS/GNSS) where UTC time is not available. This case will correspond to the ADS-B transmitting subsystem being in Timing State 2 or 3

2.2.5.4.2 Position and Velocity (UTC Coupled, Timing State 1)

At the time of ADS-B message transmission as determined in Section 2.2.5.3.1, position and velocity information encoded in the Latitude, Longitude, N-S Velocity, and E-W Velocity fields shall be valid as of the immediately previous 1 PPS Time Mark. Specifically, NO extrapolation to the time of transmission is to be performed.

2.2.5.4.3 Position and Velocity (Non-UTC coupled) *Future Definition*

2.2.5.4.4 Other Message Payload Fields (UTC or Non-UTC Coupled)

Any change in information affecting the ADS-B message payload fields shall be reflected in the encoding of that field, provided that the change occurs and is available to the ADS-B transmitting subsystem within at least ***X*** milliseconds prior to the next scheduled ADS-B message containing that field. Table 2-15 below shows the value of ***X*** for each field.

Table 2-14. Latency of ADS-B Message Payload Fields

ADS-B Message Payload Field	Value of X (Section 2.2.5.4.4)
25-Bit UAT Address	1000
Latitude	Section 2.2.5.4.2 and 2.2.5.4.3 applies
Longitude	Section 2.2.5.4.2 and 2.2.5.4.3 applies
NUCp	100
Turn Indicator	100
Horizontal Pos Available	100
UTC Coupled	100
N-S Velocity	Section 2.2.5.4.2 and 2.2.5.4.3 applies
E-W Velocity	Section 2.2.5.4.2 and 2.2.5.4.3 applies
Pressure Altitude	100
Pressure Altitude Rate	100
A/G State	100
Geodetic Height Difference	100
Height Valid	100
Emergency/Priority Status	100
Geodetic Height Difference Rate	100
Aircraft Category subfield	Not changable
Flight ID subfield	1000
Message Start Opportunity	Must use value established by ADS-B transmitting subsystem for the current frame

2.2.6 Receiver Characteristics

2.2.6.1 Sensitivity

A maximum desired signal level of [–93] dBm applied at the antenna terminals shall produce a message success rate of 90% or better.

2.2.6.2 Amplitude Discrimination of Overlapping ADS-B Messages

A 90% or better message success rate for the stronger of two overlapping desired signals shall result when the level of the stronger signal is at –80 dBm and the stronger signal is [6 dB] above the weaker signal under the following conditions:

a. the stronger signal and weaker signal align within +/- 5 usec

b. the weaker signal precedes the stronger signal by 100 usec

2.2.6.3 Frequency Capture Range

The receiver shall be capable of successful message detection with the maximum permitted signal frequency offset plus air-air doppler at 1200 knots closure/opening. [approximately 20 khz? How do we generate this signal?]

2.2.6.4 Desired Signal Dynamic Range

The receiver shall continue to achieve a 90% message success rate when the desired signal level is increased to [-10 dBm].

2.2.6.5 Baud Rate Offset Tolerance

A 90% message success rate shall be achieved when the desired signal is subject to a symbol rate offset of +/-100 ppm.

2.2.6.6 Rejection of Out-of-Band Signals

A 90% message success rate shall be achieved when an unmodulated continuous wave interfering signal of [-30 dBm] is combined with the desired signal at –70 dBm. The interfering signal shall be applied separately + 2 and – 2 MHz offset from f_0.

NOTE: This would establish the receiver's immunity to off channel energy radiated from DME ground stations adjacent to the UAT guard band.

2.2.6.7 Tolerance to Pulsed Interference

[Test to verify FEC operation and receiver recovery time from high level on channel interfering pulse at around –40 dBm when detecting signal near sensitivity. Test should allow for random pulse placement in R/S block and random placement of smaller pulse width in sync sequence]

2.2.6.8 Back-to-Back Message Reception

[Test to establish minimum receiver recovery time. How to specify and test? Is it important?]

2.2.6.9 Message Time of Receipt

The receiver shall declare a Message Time Of Receipt (MTOR) and include the MTOR value as part of the report issued to the on-board application systems. The MTOR value shall be accurate to [500 nanoseconds] with 95% confidence.

NOTE: The MTOR value need only be expressed in terms of offset from the 1 PPS UTC time mark just prior to reception.

2.2.7 Report Generation Requirements

2.2.7.1 When ADS-B Message Received

2.2.7.1.1 Message Integrity Requirements

No ADS-B message payload shall be forwarded as a report unless the decoding of the CRC parity and FEC parity EACH indicate that there are NO detected errors.

2.2.7.1.2 Report Generation and Integrity

a. Upon receipt of an ADS-B message with no detected errors, a report shall be issued that includes the MTOR (Section 2.2.6.8).

b. Reports shall be formatted according to Table 2-16 below where N is 16, 32, or 464 bytes for Basic ADS-B, Extended ADS-B and Ground Uplink messages respectively.

c. Reports shall be issued from the UAT receiver to on-board application systems with an integrity check at least equivalent to a CRC-16

Table 2-15. Report Format

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	(MSB)			**Report Header**				(LSB)
1				reserved				
2								(LSB)
3				**Message Time of Reception (MTOR)**				
4	(MSB)							

Byte #	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
5	(1st bit received)							
…				*<Unaltered Message Payload>*				
N+5								(Last bit received)

2.2.7.1.3 Report Header Encoding

The report header shall be encoded as shown in Table 2-17 below

Table 2-16. Report Header Encoding

Encoded Value (decimal)	**Meaning**
0-4	Reserved
5	Basic ADS-B message received
6	Extended ADS-B message received
7	Ground Uplink message received
8-255	Reserved

2.2.7.1.4 Message Time of Reception Encoding

MTOR shall be encoded in tenths of microseconds from the start of the 1 PPS UTC time mark, with the least significant byte transferred first.

2.2.7.2 When Ground Uplink Message Received

2.2.7.2.1 Message Integrity Requirements

a. Each R/S block of the Ground Uplink message shall be individually examined for message errors. The payload of each block shall be declared as valid only if there are NO detected errors resulting from CRC Parity decoding AND from FEC Parity decoding.

b. The Ground Uplink message shall be declared as valid only if both payloads are declared valid from a) above.

2.2.7.2.2 Report Generation and Integrity

a. If a) and b) of Section 2.2.7.2.1 are successful, the combined payload is assembled by the concatenation of the two payload fields in the order received.

b. Reports shall be formatted according to Table 2-16.

c. Reports shall be issued from the UAT receiver to on-board application systems with an integrity check at least equivalent to a CRC-16

2.2.8 Receiver Subsystem Throughput Requirements

2.2.8.1 Input Message Capacity

[What total ADS-B and Gnd Uplink load is reasonable in full NAS environment?]

2.2.8.2 Output Report Latency

[Need reasonable number for latency from message arrival at rx antenna to issuance of report under the load established for 2.2.8.1. Appendix K of DO-242 allows up to 100 ms for “report assembly”]

2.2.9 Special Requirements for Transceiver Implementations

2.2.9.1 Transmit-Receive Turnaround Time

The receiver shall be capable of receiving a desired signal within [2] ms of the ramp down of a transmitted signal.

2.2.9.2 Receive-Transmit Turnaround Time

The transmitter shall be capable of commencing transmission of an ADS-B message within [2] ms after arrival of a successfully received desired signal

2.2.9.3 Estimated 1 PPS

In the absence of an external 1 PPS UTC time mark, the receiver shall provide a 1 PPS UTC estimated time mark to the transmitter when at least one Ground Uplink message is received per UAT frame. This estimated time mark shall be sufficiently accurate to prevent ADS-B message transmissions from straying outside the ADS-B segment as long as the Ground Uplink messages are being received.

[When should this be a requirement? It seems this capability matters only if the installation supports an alternate navigation input to ADS-B]

2.3 Equipment Performance – Environmental Conditions

[To be provided]

2.4 Equipment Test Procedures

2.4.1 Definition of Terms and Conditions of Tests

Metric for receiver performance is the message success rate for Extended length ADS-B messages unless otherwise noted. Message success rate is observable from the report output of the receiver (or other equivalent method of observing sucessful message reception) and the known input of messages to the receiver.

All tests use normal operational interfaces and operating mode with the following exceptions:

- Some transmitter tests will be facilitated by having the transmitter under test transmit messages at a known rate greater than 1/sec.
- Some transmitter tests will be facilitated by the ability to set a fixed preset message transmit time relative to the 1 PPS time mark.
- [Do we need any special conditions for the data transmitted (e.g., different random bits for every message?]

2.4.2 Verification of UAT Transmitter Characteristics

[Need to investigate potential use of Vector Signal Analyzer (e.g., HP89441) in a single test setup that might be used to verify all requirements of this section.]

2.4.3 Verification of ADS-B Message Characteristics

[Can Vector Signal Analyzer be used to confirm proper message structure with same test procedure used for 2.4.2?]

2.4.4 Verification of ADS-B Message Payload Encoding

[Most payload fields have a one-to-one encoding of the input data bits with no operation on them by the UAT transmitting subsystem. How exhaustively do these fields need to be tested? Can the stimulus be through the various sensors in an integrated UAT/sensor installation like capstone?

Those fields requiring special procedures within the UAT transmitting subsystem (i.e., 25-bit address, A/G State, Emergency/Priority Status, Flight ID) need to be exercised.

Special case of “data not available” encoding needs to be verified for most fields.]

2.4.5 Verification of ADS-B Message Transmission Procedures

[Need to verify proper transmission under the various data input conditions.

Verify proper pseudorandom distribution of transmit times.

Verify proper MSO values get generated, applied and encoded.

Verify timing accuracy is maintained for range of MSO values

Verify proper operation of reversionary 1 PPS timing]

2.4.6 Verification of UAT Receiver Characteristics

[Verify proper TOR determination]

2.4.7 Verification of Report Generation Requirements

[Verify proper receipt of valid Basic and Extended ADS-B messages

Verify non-receipt of each message type with errors intentionally introduced]

2.4.8 Verification of Receiver Throughput Requirements

2.4.9 Verification of Special Transceiver Requirements

Section 3

Installed Equipment Performance

This section states the minimum acceptable level of performance for the equipment when installed in the aircraft. Installed performance requirements are the same as contained in section 2.2, which are verified through bench and environmental testing. Some system attributes and performance aspects may be affected by the physical installation (e.g. antenna patterns can affect system transmit and receive performance). System integrators might have several options when connecting to aircraft sensors or data sources. Some sources might lack the necessary range, resolution or accuracy to support the desired applications. This section identifies system attributes which installation techniques and choices might affect, beyond the equipment manufacturer's ability to compensate.

3.1 Installed Equipment Considerations

A complete UAT broadcast data link system consists of four functional elements:

1. Data sources for aircraft position, velocity, flight plan, status, etc.
2. Transmitter subsystem
3. Receiver subsystem
4. Applications

Each of these elements must meet the minimum requirements for an application in order for operational approval to be granted for that application. Table 3-1 is an example of a system which meets the minimum requirements for 2 generic applications. Additional guidance for determining requirements is contained in following paragraphs.

Table 3-1. Example System and Applications

[To be provided]

3.1.1 Data Sources

Data sources necessary to support an application shall meet the requirements of the operational environment, and shall meet the accuracy, range, and resolution requirements of the appropriate ADS-B equipage category.

3.1.2 Applications

Applications comprise any use of ADS-B or Ground Uplink data. Applications shall be developed in accordance with approved standards if standards exist. If approved standards do not exist, the developer shall propose a standard early in the development process to support approval of the operational concept and identify operational limitations.

First time operational approval for the use of installed UAT equipment in a given application will be accomplished via the Type Certificate (TC) or Supplemental Type Certificate (STC) approval process. Subsequent installations may be approved via the TC, STC, or field approval process. It is incumbent upon the developer to show that the system meets the requirements of the application. Operating limits of the system shall be included in an approved aircraft/rotorcraft flight manual supplement (AFMS/RFMS).

3.2 Equipment Installations

3.2.1 Aircraft Environment

Equipment shall be installed such that environmental conditions do not exceed the manufacturer's specifications during normal operations.

3.2.2 Aircraft Power Source

The supply voltage and allowable variation shall not exceed the manufacturer's specifications during normal operations. Equipment voltage and frequency tolerance characteristics shall be compatible with an aircraft power source of appropriate category as specified in RTCA/DO-160D.

3.2.2.1 Power Fluctuation

The equipment shall retain memory of variable data through aircraft power transfer, which occurs during normal operation. Typical power transfer involves switching from external power to internal power, either battery or APU generator, or to engine driven generator(s). The equipment shall not require reinitialization for power transfer (i.e. power loss) for a period up to 0.5 second maximum. Power transfer shall not latch a failure indication. Momentary failure indications, during switching, are allowed.

3.2.3 Accessibility

Controls, indicators, and displays provided for in-flight use shall be readily accessible and/or readable from the pilot's normal seated position. If two pilots are required to operate the aircraft, the controls must be readily accessible from each pilot's seated position. Adequate protection must be provided to prevent inadvertent turnoff of the equipment.

3.2.4 Indicators

If visual indicators are installed, they shall be visible and readable from the pilot's normal seated position. If two pilots are required to operate the aircraft, indicators shall be visible from each pilot's seated position. The brightness of any indicator must be adjustable to levels suitable under all cockpit ambient lighting conditions ranging from total darkness to reflected sunlight. If an indication is distracting, a means to cancel it should be provided.

3.2.5 Failure Protection

Probable failures of the UAT equipment must not degrade the normal operation of equipment or systems connected to it. The failure of connected equipment or systems must not degrade normal operation of the UAT equipment except for loss of functions which are directly dependent upon the failed equipment.

3.2.6 Failure Indication

The UAT system operational status shall be available to the flight crew. Failures resulting in the loss of ADS-B transmissions shall be annunciated to the crew. Though acceptable, dedicated ADS-B transmit and receive failure indicators are not required. Text messages, displayed to the crew until acknowledged, are acceptable. Systems which combine transmit and receive functions in a common unit may use a single annunciation to indicate a failure. When an ADS-B function is hosted in another system, the host system failure annunciation is adequate to indicate loss of ADS-B function.

3.2.7 Interference Effects

The equipment shall not be the source of objectionable conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft. If these systems are installed, check for interference when operating on [TBD DME Channels].

Note: Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. The installing facility is responsible for resolving incompatibilities between the ADS-B equipment and previously installed equipment in the aircraft.

3.3 Antenna Installation

[To be provided]

3.4 Flight Environment Data Sources

Aircraft systems and/or sensors, which supply flight environment data to the ADS-B system, shall be selected to meet the accuracy, range, and resolution requirements appropriate to the equipage category. (Accuracy, range, and resolution may be shown to be adequate by analysis.)

3.4.1 Navigation Uncertainty Category (NUC)

The system shall report (and adjust, if necessary) NUC values appropriate to the navigation source (including its operational mode) which supplies data to the ADS-B system. NUC value varies with navigation source selection and the selected sensor's current performance. If the aircraft has multiple navigation systems, NUC can vary with system selection and the mode of operation (e.g. Inertial Navigation with DME or GPS augmentation). The reported NUC value must vary to track navigation uncertainty (NUC) as it increases or decreases, corresponding to navigation system accuracy.

3.4.2 Altitude

Barometric Pressure Altitude relative to a standard pressure of 1013.25 millibars (29.92 in.Hg.) shall be supplied to the ADS-B system . Altitude data, which is correctable for local barometric pressure, shall not be supplied to the ADS-B system. The ADS-B system and the ATC transponder (if installed) shall derive Pressure Altitude from the same sensor (e.g. air data computer or encoding altimeter).

3.4.3 Surface/Air (Vertical) Status

Aircraft systems or sensors providing vertical status to the ADS-B system shall be implemented such that they provide a reliable indication that the aircraft is on the ground or airborne.

3.5 Aircraft/Vehicle Data

ADS-B messages contain information describing the aircraft or vehicle which is transmitting. It is a responsibility of the installer to insure that the vehicle information provided to the ADS-B system is correct.

3.5.1 Fixed Data

Data which do not change during operation, are selected or loaded at installation (e.g. ADS-B Emitter Category, ICAO address). Fixed data shall accurately represent the individual airplane/vehicle characteristics or registration information.

3.5.2 Variable Data

Controls used by the pilot/crew for data entry (e.g. flight number, call sign, emergency status) shall correctly perform their intended functions.

3.6 Flight Test Procedures

[how would an installer do this? With two aircraft air-air, or against a ground station that was somehow made accessible?]

Section 4

Operational Characteristics and Functional Requirements

[To be provided]

4.1 System Operation

4.2 Self Test

4.3 Controls

Appendix A

Acronyms and Definition of Terms

[To be provided]

Appendix B

MASPS Requirements vs MOPS

Table B-1: MASPS Compliance Matrix

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R2.1	When the full resolution of available aircraft data cannot be accommodated within an ADS-B message, a common quantization algorithm shall be used to ensure consistent performance across different implementations.			
R.2.2	The output of ADS-B shall be standardized so that it can be translated without compromising accuracy.			
R2.3	Time of applicability shall be provided in all reports.			
R2.4	The ADS-B system shall be capable of transmitting messages containing the information specified in the following subsections.			
R2.5	The basic identification information to be conveyed by ADS-B shall include the following elements: 1. Call Sign (see also R2.7) 2. Address (see also R2.8, R2.9) 3. Category (see also R2.11)			
R2.6	The ADS-B system design shall accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode.			
R2.7	ADS-B shall convey an aircraft call sign of up to 7 alphanumeric characters in length.			
R2.8	The ADS-B system design shall include a means (e.g., an address) to: 1 - correlate all ADS-B messages transmitted from the A/V, and 2 - differentiate it from other A/Vs in the operational domain.			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R2.9	Aircraft with Mode-S transponders using an ICAO 24 bit address shall use the same 24 bit address for ADS-B.			
R2.10	All aircraft/vehicle addresses shall be unique within the operational domain(s) applicable.			
R2.11	Aircraft/vehicle category, as defined by ICAO, shall be one of the following: 1. Light aircraft - 7,000 kgs (15,500 lbs) or less 2. Reserved 3. Medium aircraft - more than 7,000 kgs and less than 136,000 kgs (300,000 lbs) 4. Reserved 5. Heavy aircraft 136,000 kgs or more			
R2.12	Aircraft/vehicle state vector information shall include the following elements: 1. Three-dimensional position 2. Three-dimensional velocity 3. Airborne turn indication 4. Navigation uncertainty category			
R2.13	All non-stationary ADS-B subsystem installations shall provide dynamic state vector reporting.			
R2.14	Position information shall be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, and barometric altitude and geometric height.			
R2.15	All geometric position elements shall be referenced to the WGS-84 ellipsoid.			
R2.16	Horizontal latitude and longitude position shall be reported as a geometric position.			
R2.17	Both barometric pressure altitude and geometric height shall be reported, if available.			
R2.18	Barometric pressure altitude shall be reported referenced to standard temperature and pressure.			
R2.19	Altitude shall be provided with a range of -1,000 ft up to 100,000 ft.			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R2.20	The transmitting A/V shall provide the following information: 1. Horizontal Velocity Vector 2. Vertical Rate			
R2.21	ADS-B geometric velocity information shall be referenced to WGS-84			
R2.22	The horizontal velocity vector components are defined as the north-south and east-west velocity relative to the WGS-84 earth ellipsoid. Reported ranges shall be [0–250] knots on the surface and [0–4000 knots] airborne.			
R2.23	Altitude rate shall be designated as climbing or descending and shall be reported up to 32,000 feet per minute (fpm).			
R2.24	For NUCP values 8 and 9, geometric altitude rate shall be reported.			
R2.25	For other NUC values, barometric altitude rate or inertially augmented barometric altitude rate shall be reported.			
R2.26	An Airborne turn indication shall be designated as turning right, turning left, or not turning.			
R2.27	The velocity uncertainty category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data shall be as indicated in Table 2-1b: NUC_R Horiz.95% Vert. 95% 0 Unk. Unk. 1 <1 0 m/s > 50 f/s 2 < 3 m/s < 15 f/s 3 < 1 m/s < 5 f/s 4 < 0.3 m/s < 1.5 f/s			
R2.28	The ADS-B system shall be capable of supporting broadcast of emergency and priority status			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R2.29	Status shall include the following: 1. No emergency / Not reported 2. General emergency 3. Lifeguard/medical 4. Minimum fuel 5. No communications 6. Unlawful interference 7. Spare 8. Spare			
R2.30	The ADS-B system shall provide the capability to exchange Trajectory Change Point (TCP) and Trajectory Change Point + 1 (TCP+1) data defined below.			
R2.31	ADS-B transmissions shall indicate the ability of the transmitting participant to engage in path monitoring and/or de-confliction operations.			
R2.32	The transmitting A/V shall also indicate its capability to use intent information received from other participants			
R2.33	The rate shall be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2 minutes (5 minutes within the range limitations specified in Table 2-3) prior to reaching closest point of approach for class A2 (A3) equipage			
R2.34	The aircraft planning the change shall issue the TCP+1 information at least 5 minutes prior to commencing the trajectory change associated with the TCP.			
R2.35	TCP+1 information, shall be provided until commencing the change maneuver.			
R2.36	The TCP+1 required transmission rate shall be the same as that of the TCP			
R2.37	The ADS-B system shall be expandable so as to support information transfer requirements for additional applications not specifically identified in this MASPS.			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R2.38	While the individual parameter values in the table (Table 2-4a) may not be directly applicable to the ADS-B system, the ADS-B System shall support equivalent or better overall system level performance for the cited applications			
R3.1	Equipage of a class designated in Table 3-1 shall have, at a minimum, the indicated capabilities.			
R3.2	ADS-B equipage classes summarized in Table 3-1 shall provide the air-to-air coverage specified in Table 3-2(a).			
R3.3	The effective radiated power (ERP) and minimum signal detection capabilities shall support the associated pair-wise minimum operational ranges listed in Table 3-2(b).			
R3.4	Broadcast only aircraft (class B1) shall have ERP values equivalent to those of class A0, A1,or A2 as determined by own aircraft maximum speed, operating altitude, and corresponding coverage requirements			
R3.5	Ground vehicles operating on the airport surface (class B2) shall provide a 5 nmi coverage range for an A1 class receiver.			
R3.6	Such ground vehicles (class B2) shall automatically prohibit ADS-B transmissions when outside the surface movement area (i.e., runways and taxiways)			
R3.7	Fixed obstruction (class B3) broadcast coverage shall be sufficient to provide a 10 nmi coverage range from the location of the obstruction.			
R3.8	Each equipage class shall meet the required information broadcast and receiving capability at the indicated range to support the applications indicated in Table 3-3.			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R3.9	Report accuracy, update period and acquisition range requirements are derived from the sample scenarios of Chapter 2, and are specified in Table 3-3(a). The state vector report shall meet the update period and 99 percentile update period requirements for each application listed.			
R3.10	For all of the scenarios included in Table 3-4, the state vector shall be acquired with a 95% confidence by the range specified for the scenario.			
R3.11	The minimum range at which mode status and on-condition reports shall be acquired with 95% confidence is specified in Table 3-4.			
R3.12	Acquisition shall be considered accomplished when all report elements required for an operational scenario have been received by an ADS-B participant.			
R3.13	Required ranges for acquisition shall be as specified in Table 3-4.			
R3.14	The ADS-B system shall satisfy the error budget requirements specified in the table in order to assure satisfaction of ADS-B report accuracies.			
R3.15	If a smoothing filter or tracker is used in the ADS-B design, the quality of the reports shall be sufficient to provide equivalent track accuracy implied in Table 3.3-3 over the period between reports, under target centripetal accelerations of up to 0.5g with aircraft velocities of up to 600 knots.			
R3.16	For NUC_P less than 8, ADS-B latency of the reported information shall be less than 1.2 s with 95 percent confidence.			
R3.17	For NUC_P >= 8 , ADS-B latency shall be less than 0.4 s with 95% confidence.			
R3.18	The standard deviation of the report time error shall be less than 0.5 s (1 sigma).			
R3.19	The mean report time error for position shall not exceed 0.5 s.			
R3.20	The mean report time error for velocity shall not exceed 1.5 s			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R3.21	The ADS-B system shall be capable of operating in the traffic density shown by the highest curve in Figure 3-8 which indicates a total count of 1,000 units (moving and stationary) within a radius of 60 nmi.			
R3.22	The ADS-B Medium shall be suitable for all-weather operation, and ADS-B System performance will be specified relative to a defined standard interference environment for the medium.			
R3.23	Radio frequencies used for ADS-B Message transmission shall operate in an internationally allocated Aeronautical Radio Navigation bands			
R3.24	ADS-B availability shall be 0.9995 for class A0 through class A3 and class B0 through class B3 transmission subsystems.			
R3.25	ADS-B availability shall be 0.95 for class A0 receiver subsystems.			
R3.26	Class A1, A2, and A3 receiver subsystems shall have an availability of 0.9995.			
R3.27	The probability that the ADS-B System, for a given ADS-B Message Generation Function and in-range ADS-B Report Generation Processing Function, is unavailable during an operation, presuming that the System was available at the start of that operation, shall be no more than 2×10^{-4} per hour of flight.			
R3.28	The integrity of the ADS-B System shall be 10^{-6} or better on a per report basis.			
R3.29	The messages shall be correlated, collated, uncompressed, re-partitioned, or otherwise manipulated as necessary to form the output reports specifically defined in Section 3.4.3.			
R3.30	The message and report assembly processing capabilities of the receiving system shall support the total population of participants within detection range provided by the specific data link technology			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R3.31	Receiving subsystem designs must provide reports based on all decodable messages received, i.e., for each participant the report shall be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is received from that participant.			
R3.32	The applicable reports shall be made available to the applications on a continual basis in accordance with the local system interface requirements.			
R3.33	If the ADS-B design uses the ICAO 24-bit address, then there shall be agreement between the address currently being used by the Mode S transponder and the reported ADS-B address, for aircraft with both transponder and ADS-B.			
R3.34	The pressure altitude reported in ADS-B (SV element 11) shall be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B			
R3.35, R3.36	For systems utilizing segmented messages for SV data, critical state vector fields not updated in the current received message shall be estimated when the report is updated; otherwise fields shall be updated as new data is received.			
R3.37	The time of applicability relative to local system time shall be updated with State Vector report update.			
R3.38	For other elements of the SV report the assembly function shall provide update when received or indicate 'no data available' if none is received in the preceding 10 second period.			
R3.39	The NUC data elements shall be those determined by the originating participant as defined in Section 2.1.2.2.4.			
R3.40	ADS-B State vector reports for each participant shall be available to applications as soon as each participant is detected.			

MASPS Ref. #	Requirement	MOPS Ref. #	Title / Description	Compliance
R3.41	For each participant the Mode Status report shall be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant.			
R3.42	The time of applicability relative to local system time shall be updated with every Mode Status report update.			
R3.43	For all elements of the MS report the assembly function shall provide update when received or indicate 'no data available' if none is received in the preceding 10 second period			
R3.44	For each message received containing on-condition information, the on-condition report shall be updated and made available to ADS-B applications.			
R3.45	The time of applicability relative to local system time shall be updated with every On-Condition report update.			

Note: *MG = Message Generation; ME = Message Exchange; ME(T) = Message Exchange (transmit); ME® = Message Exchange (receive); RG = Report Generation*

Appendix C

Example ADS-B Message Encoding

Data Element Description	**Total Bits**	**Example Values**	**Bit Pattern**	**Hexadecimal (LSB first)**
TYPE 0 SUPPLEMENTAL MESSAGE				
Ramp up	4		0000	
Synchronization Sequence			111010101100110111011010010011100010	
Length Identifier			11110000	
Basic SV Payload			*<all in double border box below>*	
Type 0 Supplemental			*<all in triple border box below>*	
CRC Parity				
FEC Parity				
Ramp Down				
BASIC SV PAYLOAD FIELDS				
25-Bit UAT Address				
Latitude				
Longitude				
NUCp				
Turn Indicator				
Hor. Pos Avail				
UTC Coupled				
N-S Velocity				
E-W Velocity				
Pressure Altitude				
Pressure Alt. Rate				
A/G State				
TYPE 0 SUPPLEMENTAL PAYLOAD FIELDS				
Payload Type Code		0	000	
Future Definition				
Geodetic Ht Difference				
Height Valid				
Emergency/Priority/IDEN				
Geodetic Ht Difference				
Future Definition				
Byte Pair #1*				
Byte Pair #2*				
Byte Pair #3*				
Message Start Opportunity				
Timing State				
Future Definition				
*Value derived from encoding of the following subfield values per Section 2.2.4.2.8				
Aircraft Category		"Small" from Table 2-11		
Flight ID		"ABC1234<SP>"		

[To be provided]

Appendix D

Ground Uplink Message Payload

[To be provided]